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(19)

(11) Publication number: 0 407 579 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art.
158(3) EPC

(21) Application number: 89902534.0

(22) Date of filing: 15.02.89

(86) International application number:
PCT/JP89/00154

(87) International publication number:
WO 89/07416 (24.08.89 89/20)

(30) Priority: 15.02.88 JP 32083/88

(43) Date of publication of application:
16.01.91 Bulletin 91/03

(84) Designated Contracting States:
DE FR GB

(51) Int. Cl.5: A61B 5/05, G01N 24/08

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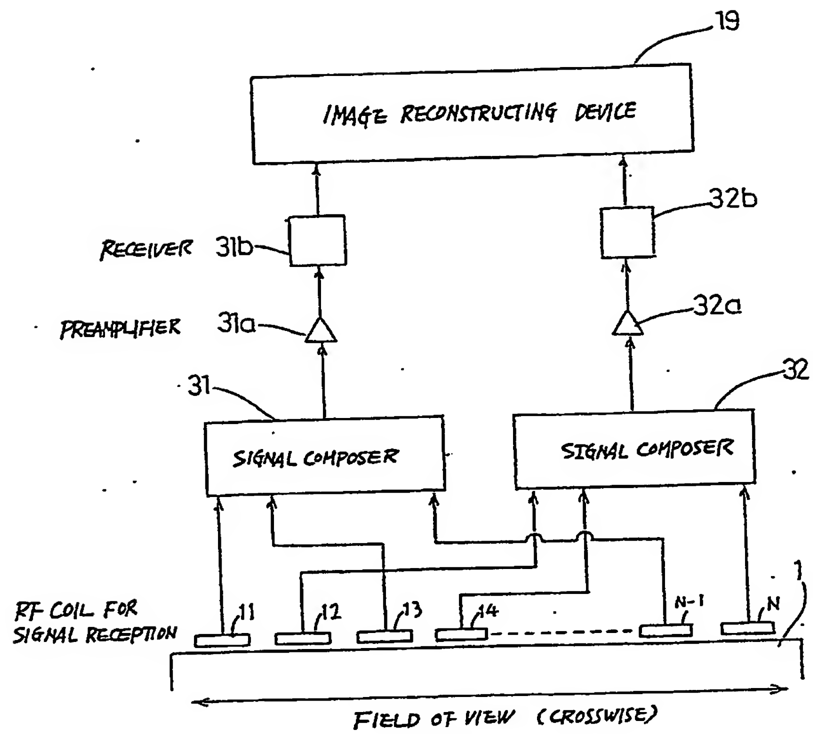
(54) MAGNETIC RESONANCE IMAGING DEVICE.

(57) A magnetic resonance imaging device of the invention effects the imaging by the multi-coil method while decreasing the hardware amount in the MR signal receiving system and decreasing the amount of operation for reconstituting the image. The magnetic resonance imaging device comprises a plurality of high-frequency coils for receiving MR signals that are arranged along the surface of an object of inspection and that have sensitive regions each overlapping with the neighboring ones, a plurality of signal synthesizers which are provided for the groups of MR signal receiving high-frequency coils whose sensitive regions are not overlapped by one another and which synthesize the signals received from the receiving high-frequency coils of the corresponding groups into one reception signal, a plurality of receivers which effect signal processing such as detection, A/D conversion and the like for the output signals from these plurality of signal synthesizers, and an image reconstitution device which reconstitutes the images based on output signals from the plurality of receivers and which synthesizes an image using a plurality of the reconstituted images.

EP 0 407 579 A1

FIG. 1


19
IMAGE RECONSTRUCTING DEVICE
RECEIVER
31b
32b
PREAMPLIFIER
31a
32a
31
32
SIGNAL COMPOSER
SIGNAL COMPOSER
RF COIL FOR
SIGNAL RECEPTION
11
12
13
14
N-1
N
1
FIELD OF VIEW (CROSSWISE)

TITLE MODIFIED
see front page

SPECIFICATION

TITLE OF THE INVENTION:

Magnetic Resonance Imaging Apparatus

TECHNICAL FIELD:

The present invention relates to a magnetic resonance imaging apparatus that reconstructs an image using magnetic resonance signals received by a plurality of radio frequency coils.

PRIOR ART:

With the magnetic resonance imaging (MRI) apparatus, radio frequency magnetic resonance signals (MR signals) generated in an object body are received by radio frequency coils (RF coils). This process may operate on the so-called multiple coil method whereby a plurality of RF coils receive MR signals, as illustratively shown in Fig. 5. This figure depicts a prior art case where a tomogram is taken of a backbone 2 in an object body 1. A plurality of RF coils 3 are positioned on the back of the object body 1 along the backbone 2 in order to receive the MR signals from within the body. Fig. 6 highlights an RF signal receiving system of a prior art MRI apparatus operating on the multiple coil method. In Fig. 6,

reference numerals 11 through N designate a plurality of RF coils arranged parallel to the slice plane of the object body 1. RF signals received by the RF coils are amplified respectively by preamplifiers 11a through Na. The amplified signals enter receivers 11b through Nb that perform such signal processes as frequency conversion, amplification, detection and analog-to-digital (A/D) conversion. The processed signals then enter an image reconstructing device 19. The image reconstructing device 19 reconstructs a plurality of images based on the multiple input signals, and combines these images into a single image. Reference numeral 20 is the object body's sensitive area corresponding to each of the RF coils 11 through N. Adjoining sensitive areas have a mutually overlapping portion therebetween. The images stemming from these sensitive areas are reconstructed by the image reconstructing device 19 into a single image. This multiple coil method is characterized by the fact that the overall sensitive region corresponding to the received MR signals is extensive in the field of view (crosswise) but shallow in the object body's depth direction. That is, the method is suitable for the imaging of backbones or like areas with good S/N ratios. One disadvantage of the multiple coil method is the need for an expanded hardware

construction involving pluralities of preamplifiers and receivers associated with the multiple RF coils. Another disadvantage is that the image reconstructing device 19 is required to perform greater amounts of computations for image reconstruction because the device must reconstruct each one of the images associated with the sensitive areas of the coils based on the RF signals coming therefrom.

OBJECT AND SUMMARY OF THE INVENTION:

It is therefore an object of the present invention to provide a magnetic resonance imaging (MRI) apparatus which reduces the bulk of the hardware for MR signal reception and lowers the amount of computations for image reconstruction while operating on the multiple coil method for imaging.

In carrying out the invention, there is provided an MRI apparatus comprising a plurality of radio frequency (RF) coils, a plurality of signal composers, a plurality of receivers, and an image reconstructing device. The RF coils are positioned on the surface of an object body to receive MR signals coming therefrom, the sensitive areas of the adjoining RF coils having a mutually overlapping portion therebetween. The signal composers are provided to address each group of RF coils whose sensitive areas do

not overlap. One signal composer composes a single received signal out of the signals from the RF coils in one group. The receivers carry out such signal processes as detection and A/D conversion on the signals coming from the signal composers. The image reconstructing device reconstructs images based on the output signals from the receivers and puts these images together into a single reconstructed image.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a view conceptually showing the construction of a first embodiment of the present invention;

Figs. 2A through 2C are views that help to describe how images are reconstructed by the first embodiment;

Fig. 3 is a view conceptually depicting the construction of a second embodiment of the present invention;

Fig. 4 is a view of an alternative arrangement of RF coils for use with the embodiment;

Fig. 5 is a view showing how RF coils are illustratively used by the multiple coil method; and

Fig. 6 a view conceptually describing the construction of a prior art MRI apparatus operating on the

multiple coil method.

BEST MODE FOR CARRYING OUT THE INVENTION:

Preferred embodiments of the present invention will now be described by referring to the accompanying drawings. Fig. 1 is a conceptual view of how the first embodiment of the invention is constructed. In Fig. 1, reference numerals 11 through N are a plurality of RF coils positioned along the slice plane of an object body 1. As in the prior art example of Fig. 6, The RF coils 11 through N are associated with their respective sensitive areas. The sensitive areas of adjoining RF coils share an overlapping portion between. Numeral 31 is a first signal composer which receives signals from odd-numbered RF coils 11 through N-1 and which composes a signal out of these input signals. Numeral 32 is a second signal composer which receives signals from even-numbered RF coils 12 through N and which also composes a signal out of these input signals. Numerals 31a and 32a are preamplifiers that respectively amplify the outputs from the signal composers 31 and 32. Numerals 31b and 32b are receivers that perform such signal processes as frequency conversion, amplification, detection and A/D conversion on the output signals from the preamplifiers 31a and 32a, respectively.

Numeral 19 is an image reconstructing device that reconstructs an image using the output signals from the receivers 31b and 32b. There are also provided mechanisms for generating a magnetostatic field, a plurality of gradient magnetic fields, and a radio frequency magnetic field affecting the object body 1. These mechanisms are the same as those of conventional MRI apparatus and are thus omitted from the figure.

The first embodiment works as follows. Of the RF coils that have received MR signals, the odd-numbered RF coils 11 through N-1 forward their MR signals to the first signal composer 31. The signal composer 31 composes the received signals into a signal received signal. Likewise, the even-numbered RF coils 12 through N forward their MR signals to the second signal composer 32 which composes these signals into another received signal. The received signals from the signal composers 31 and 32 are amplified by the preamplifiers 31a and 32a, respectively. The amplified signals are subjected to such signal processes as frequency conversion, amplification, detection and D/A conversion by the receivers 31b and 32b. The processed signals then enter the image reconstructing device 19. It is to be noted that while the sensitive areas of adjoining RF coils overlap with one another, every second coil,

i.e., any of odd-numbered or even-numbered RF coils, does not share an overlapping sensitive portion with its neighboring coils. Thus when the signals from within the group of odd-numbered or even-numbered RF coils are composed by the signal composer 31 or 32, the signals do not cancel one another because of their overlapping portions. This allows two different images to be reconstructed based on the two signals composed by the signal composers 31 and 32. The received signal from the first signal composer 31 causes shaded images of Fig. 2A to be reconstructed, while the signal from the second signal composer 32 results in reconstructed images shown shaded in Fig. 2B. In these figures, reference numerals 41 through 44 are the reconstructed images respectively corresponding to the sensitive areas of the RF coils 11 through 14. The image reconstructing device 19 composes the reconstructed images from these two sections into one image 50 shown in Fig. 2C. The image 50 is the sum of all images associated with the sensitive areas of all RF coils. This embodiment only requires two receiving sections (each comprising preamplifiers, receivers, etc.) and two passes of image reconstruction computations regardless of the number of the RF coils configured. In an example where eight RF coils are used, the bulk of the

receiving section hardware and the amount of image reconstruction computations are both reduced to one fourth of the levels of the comparable prior art.

When feeble signals from the RF coils 11 through N are directly input to signal composers whose signal loss level is not sufficiently low, the signal-to-noise ratio may deteriorate. This is where the second embodiment of the invention comes in. With the second embodiment, the signals from the RF coils 11 through N are amplified by preamplifiers 11a through Na before they are input to the signal composers 31 and 32, as shown in Fig. 3. Although the number of preamplifiers remains the same, the bulk of the hardware downstream of the receivers may be reduced, and so is the amount of the image reconstruction computations involved. The present invention may also be practiced with an alternative arrangement of RF coils. Instead of being positioned in a single row, the multiple RF coils may be arranged in a two-dimensional pattern, as depicted in Fig. 4. The area of the 2D coil pattern is the same as that of the single-row coil arrangement. Of the nine RF coils shown in Fig. 4, those not adjoining one another are connected to a different signal composer for signal composition. That is, three RF coils marked "A" are connected to a signal composer, three RF coils marked "B"

to another signal composer, two RF coils marked "C" to yet another signal composer, and one RF coil is connected to one signal receiver. Thus there are four received signals made available, which means that nine RF coils require only four sections of the signal receiving hardware and four passes of image reconstruction computations.

It is to be understood that while the invention has been described in conjunction with specific embodiments, it is evident that many alternatives, modifications and variations will become apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended that the present invention embrace all such alternatives, modifications and variations as fall within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A magnetic resonance imaging apparatus comprising:

a plurality of radio frequency (RF) coils which receive magnetic resonance (MR) signals and which are positioned along the surface of an object body, said coils corresponding to sensitive areas of said object body, said sensitive areas sharing an overlapping portion therebetween where their corresponding RF coils adjoin one other;

a plurality of signal composers each associated with a different group of said RF coils whose corresponding sensitive areas do not overlap with one another, said each composer taking received signals from the RF coils within one group and composing said signals into a single received signal;

a plurality of receivers for performing such signal processes as detection and A/D conversion on the output signals from said signal composers; and

an image reconstructing device which reconstructs images from the output signals from said multiple receivers and composes said reconstructed images into a single image.

2. A magnetic resonance imaging apparatus according

to claim 1, further comprising a plurality of preamplifiers between said plurality of signal composers and said plurality of receivers, said preamplifiers amplifying the output signals from said signal composers before said signals reach said receivers.

3. A magnetic resonance imaging apparatus according to claim 1, further comprising a plurality of preamplifiers between said plurality of RF coils and said plurality of signal composers, said preamplifiers amplifying the received signals from said RF coils.

4. A magnetic resonance imaging apparatus according to claim 1, wherein said plurality of RF coils are arranged in a single row.

5. A magnetic resonance imaging apparatus according to claim 1, wherein said plurality of RF coils are arranged in a two-dimensional pattern.

FIG. 1

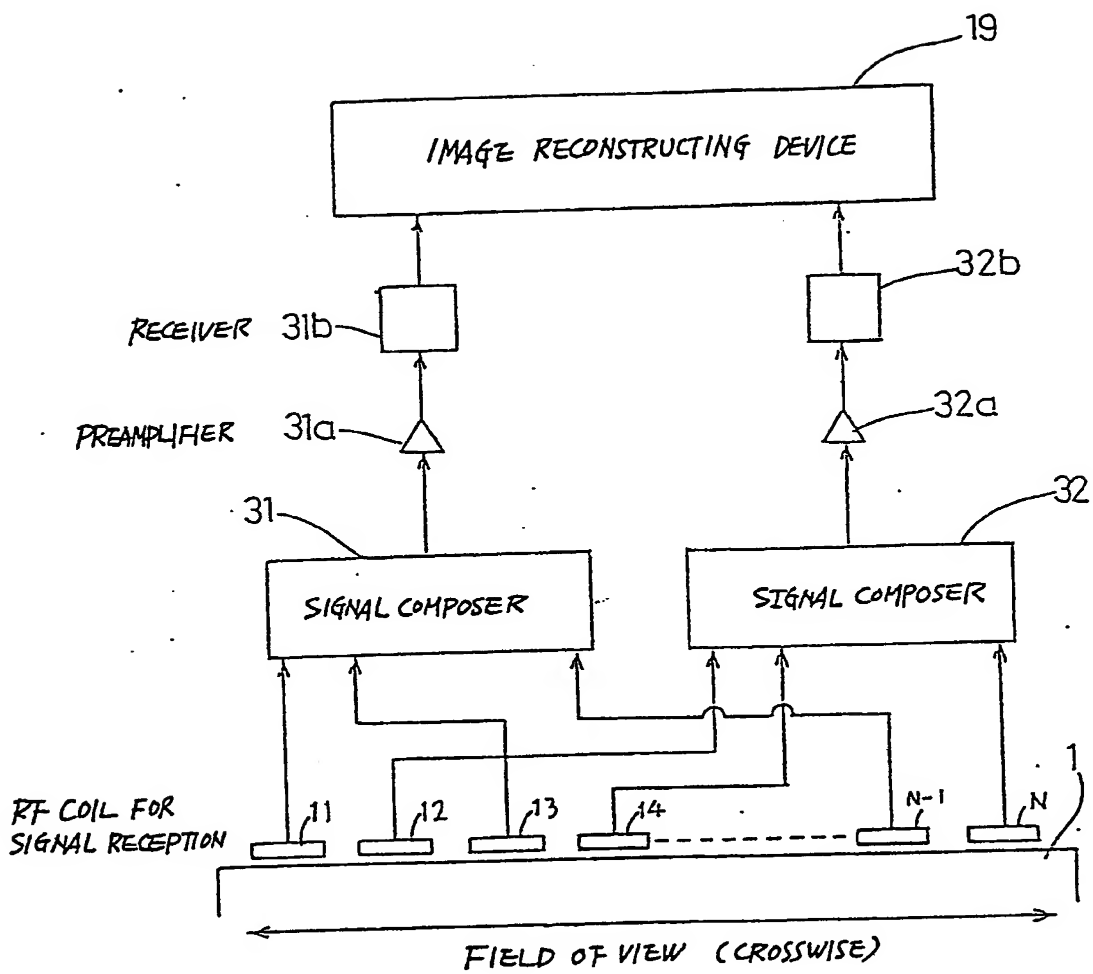

19
IMAGE RECONSTRUCTING DEVICE
32b
RECEIVER 31b
PREAMPLIFIER 31a
32a
31
32
SIGNAL COMPOSER
SIGNAL COMPOSER
RF COIL FOR SIGNAL RECEPTION
11
12
13
14
N-1
N
1
FIELD OF VIEW (CROSSWISE)

FIG. 2A

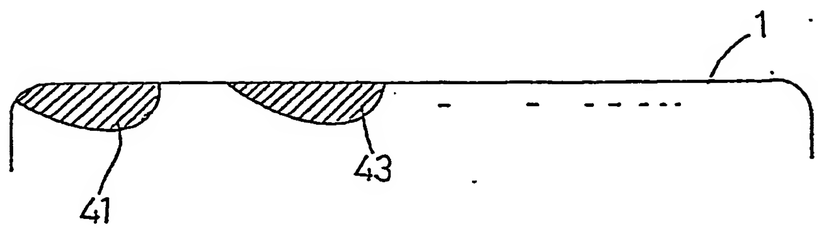


FIG. 2B

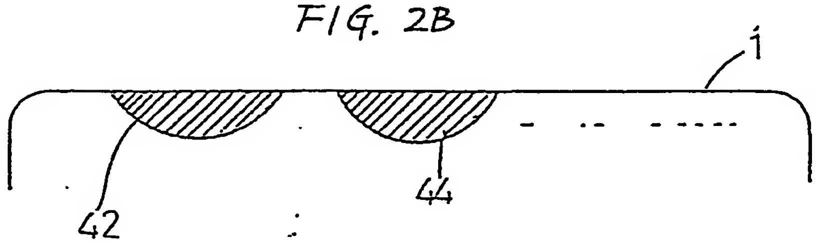


FIG. 2C

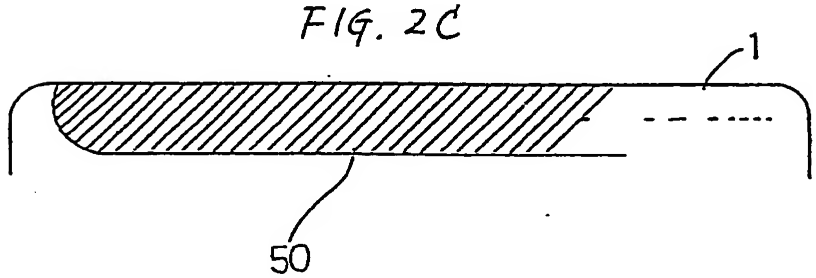


FIG. 3

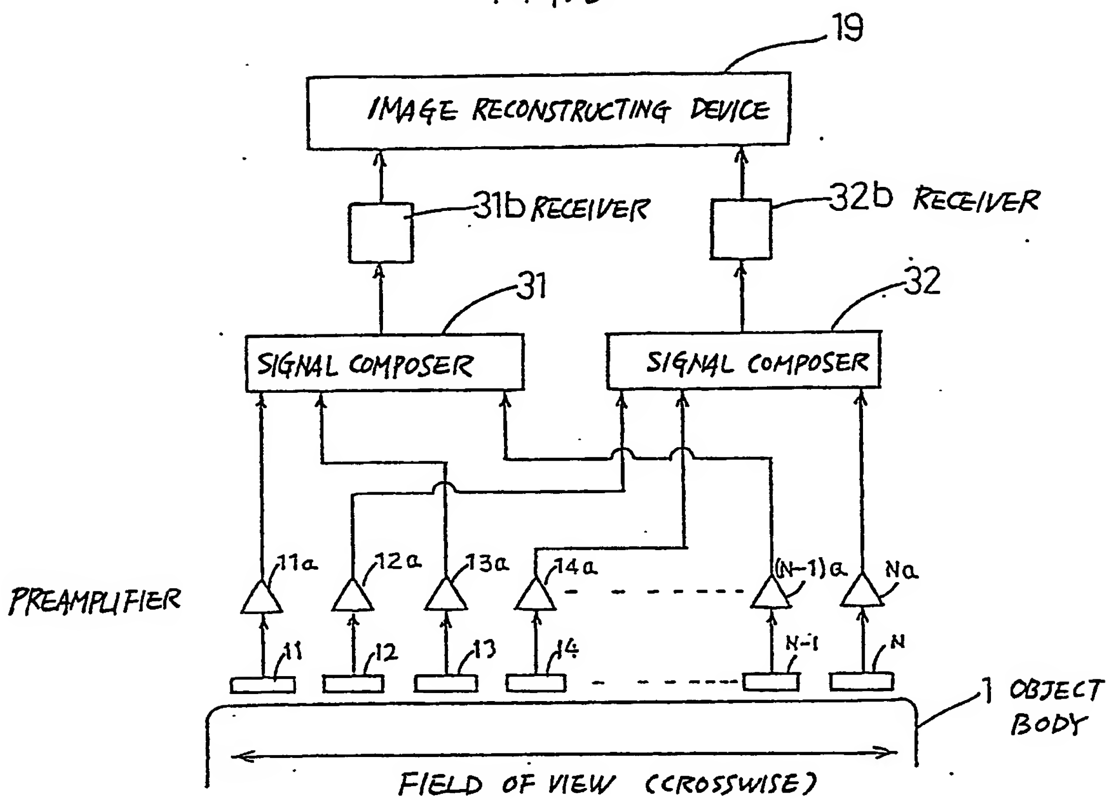

19
IMAGE RECONSTRUCTING DEVICE
31b RECEIVER
32b RECEIVER
31
32
SIGNAL COMPOSER
SIGNAL COMPOSER
PREAMPLIFIER
11a
12a
13a
14a
(N-1)a
Na
11
12
13
14
N-1
N
1 OBJECT BODY
FIELD OF VIEW (CROSSWISE)

FIG. 4

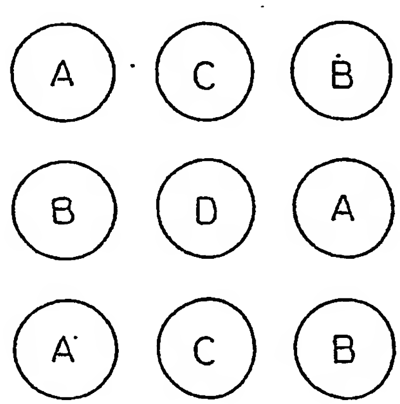

A
C
B
B
D
A
A
C
B

FIG. 5

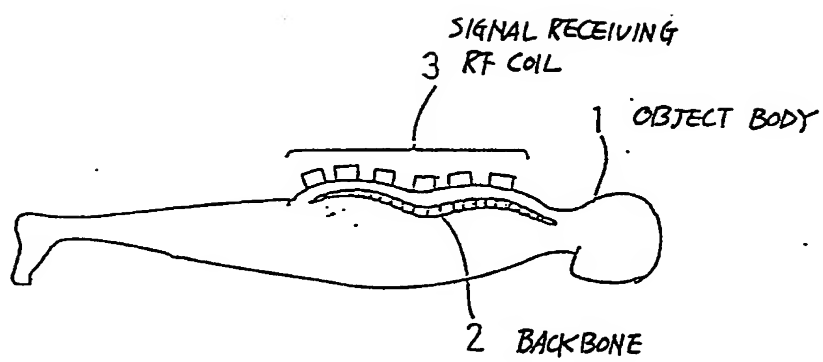
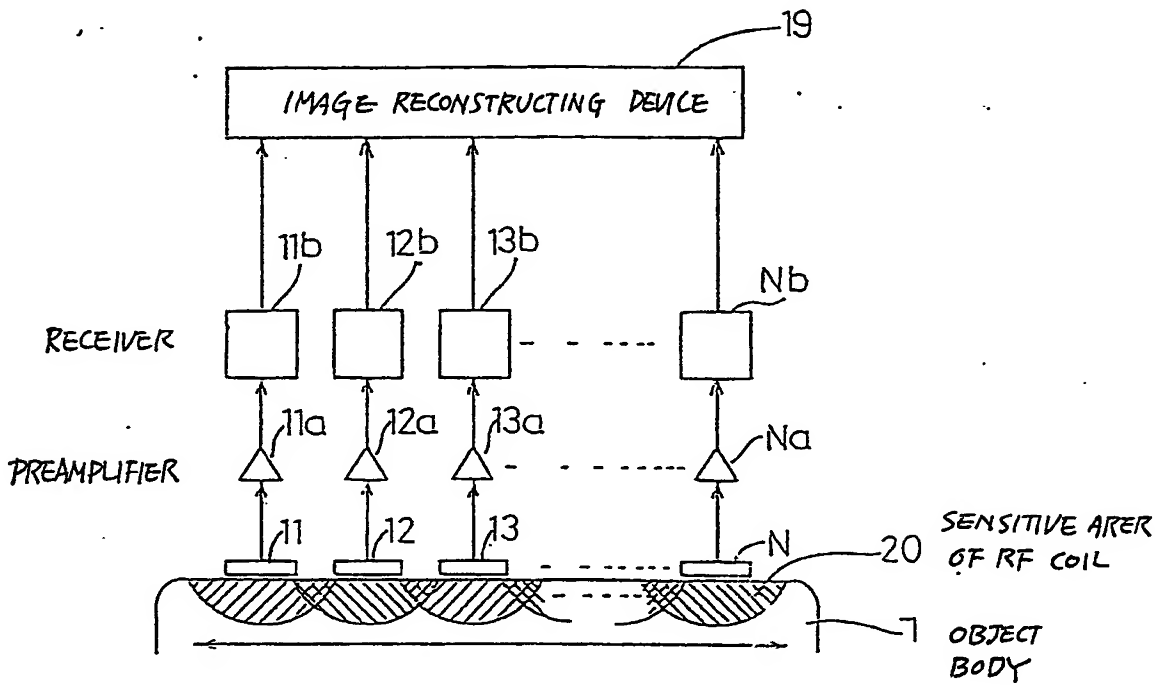


FIG. 6


19
IMAGE RECONSTRUCTING DEVICE
11b
12b
13b
Nb
RECEIVER
11a
12a
13a
Na
PREAMPLIFIER
11
12
13
N
20
SENSITIVE AREA OF RF COIL
7
OBJECT BODY

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP89/00154

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl^4 A61B5/05, G01N24/08

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	A61B5/05, A61B10/00, G01N24/08

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho	1926 - 1989
Kokai Jitsuyo Shinan Koho	1971 - 1989

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	JP, U, 63-137614 (Shimadzu Corporation) 9 September 1988 (09. 09. 88) Fig. 3 (Family: none)	1-5
Y	JP, A, 52-127389 (National Research Development Corporation) 25 October 1977 (25. 10. 77) Page 9, upper left column, line 7 to lower right column, line 6, Fig. 8 & US, A, 4115730	1-5

* Special categories of cited documents: [10]

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
April 20, 1989 (20. 04. 89)	May 15, 1989 (15. 05. 89)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	

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